Advanced Projects in Exoplanets

The RM Effect

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Transiting Exoplanets

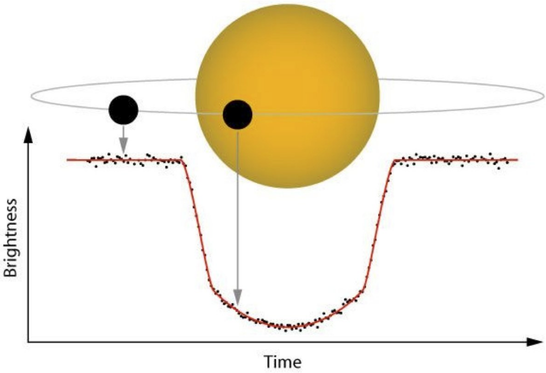


Figure: *Credit ESO*

Rossiter-McLaughlin Effect

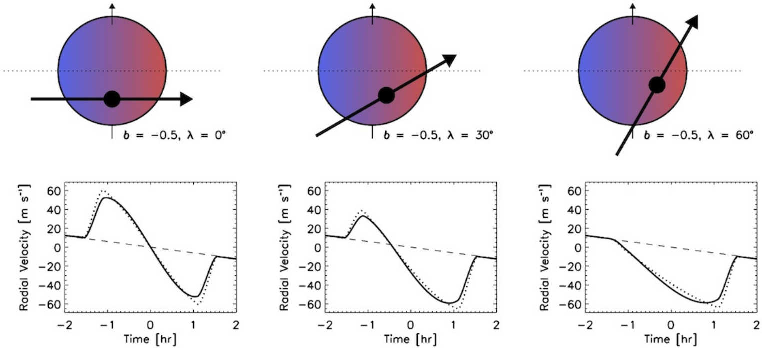


Figure:
https://wasp-planets.net/tag/rossiter-mclaughlin-effect/

Our Model - Linear

Planet moves in straight line in front of the star

This path is determined by:

- Projected obliquity
- Impact parameter

This model is not physical

Keplers Equations

To get $r(t)$:
Calculate mean anomaly:

$$M(t) = \sqrt{\frac{G(M_\star + M_p)}{a^3}} \cdot (t - t_p).$$

Calculate eccentric anomaly by numerical iteration:

$$E_{n+1} = E_n - \frac{E_n - esin(E_n) - M(t)}{1 - esin(E - n)}.$$

Calculate true anomaly:

$$\nu(t) = 2\tan^{-1}(\left(\frac{1+e}{1-e}\right)^{1/2} \tan(E(t)/2)).$$

Calculate separation:

$$r(t) = a\frac{1 - e^2}{1 + ecos(\nu(t))}.$$

Our Model - Physical version

Planet orbits the star.
Keplers equation is solved for input parameters.
The path is determined by:
a, e, i, ω, $M_\star$, M_p, t_p, λ, $R_p/R_\star$ and $v\sin(i_\star)$.
Much more resource heavy, but also correct

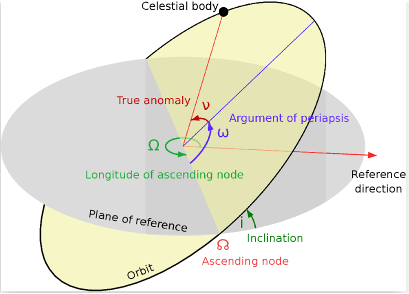


Figure: Credit: Wikipedia user Lassuncty

Modelling Planet Orbit

Calculate projected coordinates of the planet:

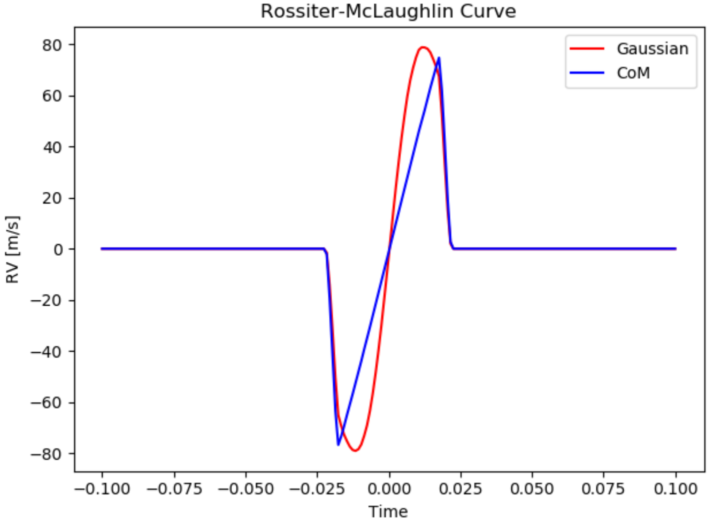
$$
\begin{aligned}
X_i &= -r cos(\omega + \nu), \\
Y_i &= -r sin(\omega + \nu) cos(i).
\end{aligned}
$$

$$
\begin{aligned}
X &= X_i cos(\lambda) + Y_i sin(\lambda), \\
Y &= -X_i sin(\lambda) + Y_i cos(\lambda), \\
Z &= r sin(\omega + \nu) sin(i).
\end{aligned}
$$

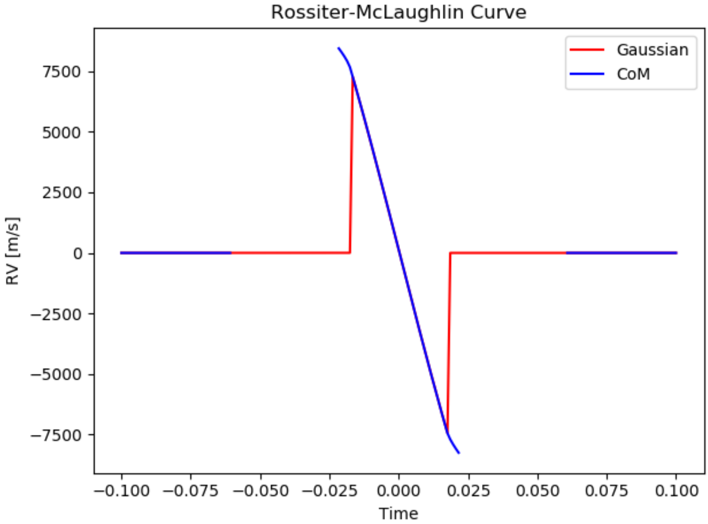
Our Model - Outputs

[Video here]

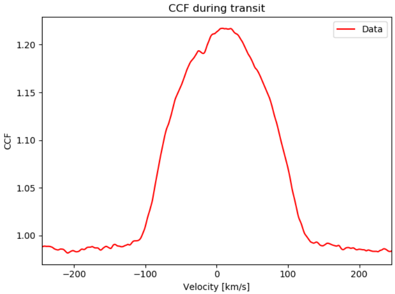
Our Model - Outputs



Our Model - Outputs

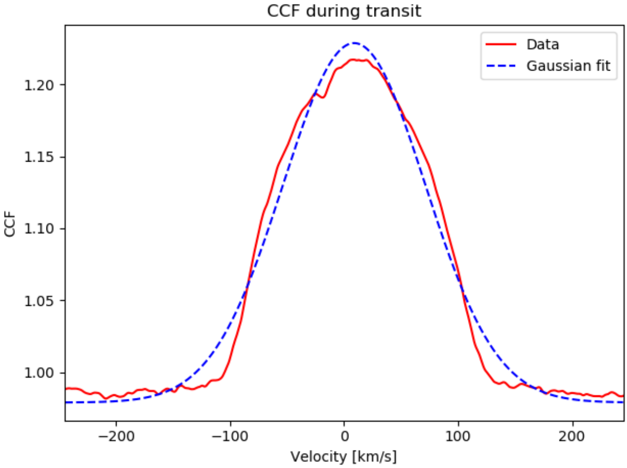


Data

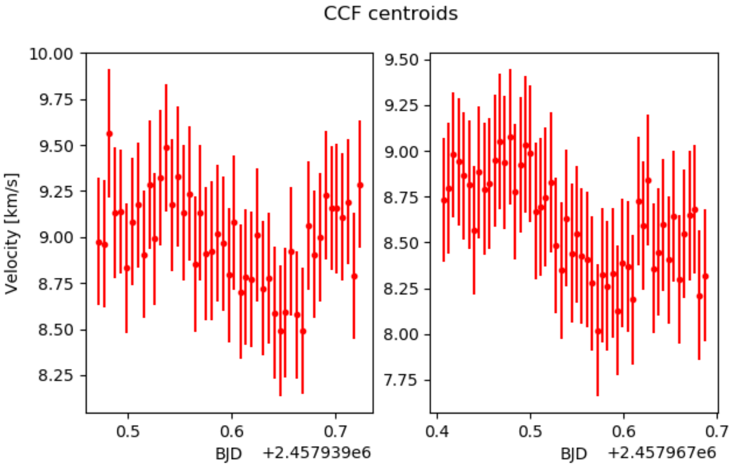


CCF during transit
Data
1.20
1.15
1.10
1.05
1.00
CCF
−200
−100
0
100
200
Velocity [km/s]

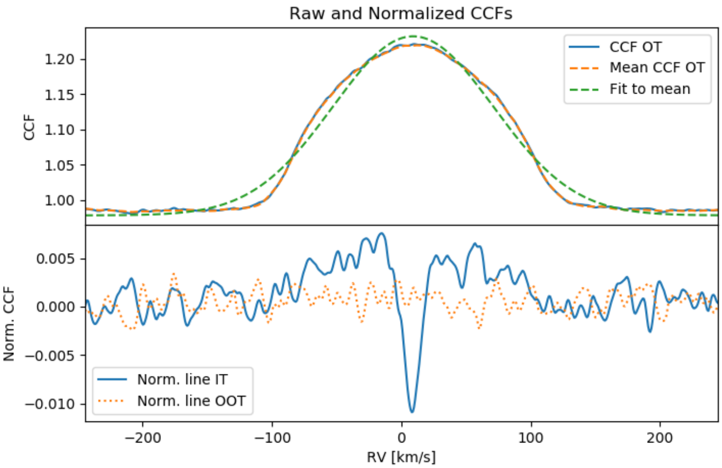
Data - The stellar line



Data - The Transit

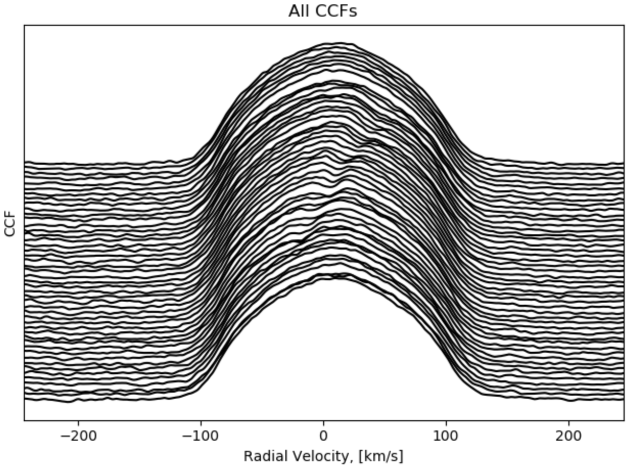


Data - The 'Planet Line'

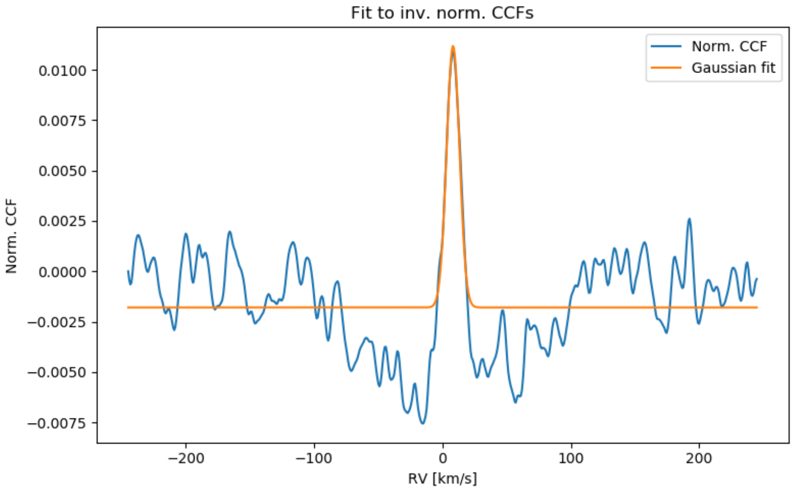


Data - The RM-effect

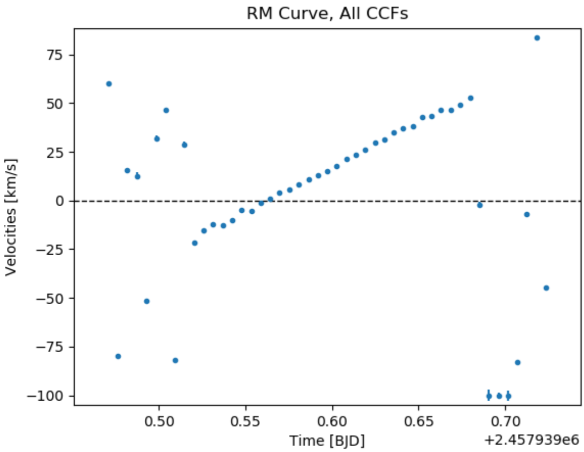
Data



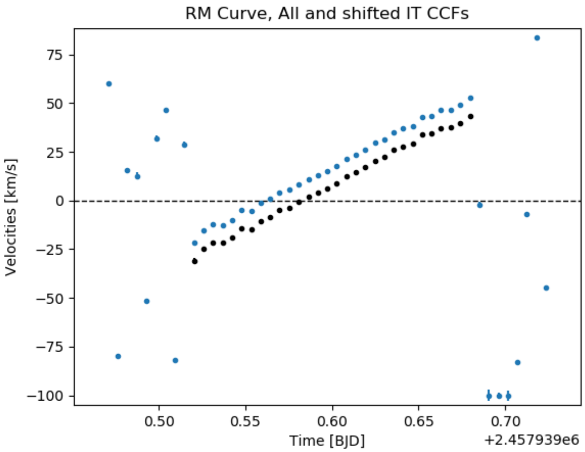
Data - Fit to CCF



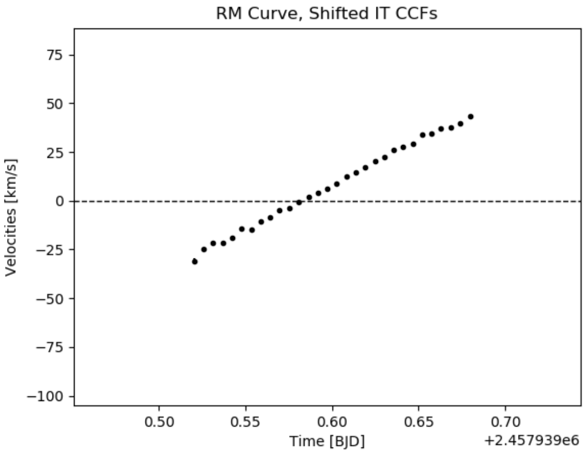
Data - RM curve



Data - RM curve



Data - RM curve



The Fit - System Parameters

Variables:

- λ
- ω
- $v\sin(i_\star)$

Constants:

- $t_p = 0$
- $a = 4.756R_\star$
- $e = 0$
- $M_\star = 1.72M_\odot$
- $M_p = 3.7M_J$
- $\frac{R_p}{R_\star} = 0.0735$
- $\omega = 90^\circ$

Fitting with curvefit

Linear fit